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UTILITY PATENT APPLICATION TRANSMITTAL
(Only for new nonprovisional applications under 37 CFR 1.53(b))

Attorney Docket No.	042390.P8746
First Inventor or Application Identifier	Tinku Acharya
Title	METHOD OF USING HUE TO INTERPOLATE COLOR PIXEL SIGNALS
Express Mail Label No.	EL034434615US

APPLICATION ELEMENTS
See MPEP chapter 600 concerning utility patent application contents

ADDRESS TO:
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1. ☒ Fee Transmittal Form
   (Submit an original, and a duplicate for fee processing)

2. ☒ Specification   [*Total Pages 21*]
   (preferred arrangement set forth below)
   - Descriptive title of the Invention
   - Cross References to Related Applications
   - Statement Regarding Fed sponsored R & D
   - Reference to Microfiche Appendix
   - Background of the Invention
   - Brief Summary of the Invention
   - Brief Description of the Drawings *(if filed)*
   - Detailed Description
   - Claim(s)
   - Abstract of the Disclosure

3. ☒ Drawing(s) *(35 U.S.C. 113)* [*Total Sheets 2*]

4. Oath or Declaration   [*Total Pages 6*]
   a. ☐ Newly executed (original copy)
   b. ☐ Copy from a prior application (37 C.F.R. § 1.63(d))
      (for continuation/divisional with Box 16 completed)
      i. ☐ DELETION OF INVENTOR(S)
         Signed statement attached deleting
         inventor(s) named in the prior application,
         see 37 CFR §§ 1.63(d)(2) and 1.33(b).

NOTE FOR ITEMS 1 & 13: IN ORDER TO BE ENTITLED TO PAY SMALL ENTITY FEES, A SMALL ENTITY STATEMENT IS REQUIRED (37 C.F.R. § 1.27), EXCEPT IF ONE FILED IN A PRIOR APPLICATION IS RELIED UPON (37 C.F.R. § 1.28).

5. ☐ Microfiche Computer Program *(Appendix)*

6. Nucleotide and/or Amino Acid Sequence Submission
   (if applicable, all necessary)
   a. ☐ Computer Readable Copy
   b. ☐ Paper Copy (identical to computer copy)
   c. ☐ Statement verifying identity of above copies

ACCOMPANYING APPLICATION PARTS

7. ☐ Assignment Papers (cover sheet & document(s))
8. ☐ 37 C.F.R. § 3.73(b) Statement   ☐ Power of Attorney
   (when there is an assignee)
9. ☐ English Translation Document *(if applicable)*
10. ☒ Information Disclosure   ☒ Copies of IDS
    Statement (IDS)/PTO - 1449   Citations
11. ☐ Preliminary Amendment
12. ☒ Return Receipt Postcard (MPEP 503)
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13. ☐ *Small Entity   ☐ Statement filed in prior application,
    Statement(s)   Status still proper and desired
14. ☐ Certified Copy of Priority Document(s)
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15. ☐ Other: ....
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    ....

16. If a CONTINUING APPLICATION, *check appropriate box, and supply the requisite information below and in a preliminary amendment:*
☐ Continuation   ☐ Divisional   ☒ Continuation-in-part (CIP)   of prior application No: 09/410, 870

*Prior application Information: Examiner*_____   *Group/Art Unit:*_____

For CONTINUATION or DIVISIONAL APPS only: The entire disclosure of the prior application, from which an oath or declaration is supplied under Box 4b, is considered a part of the disclosure of the accompanying continuation or divisional application and is hereby incorporated by reference. The incorporation can only be relied upon when a portion has been inadvertently omitted from the submitted application parts.

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APPLICATION FOR UNITED STATES LETTERS PATENT

FOR

METHOD OF USING HUE TO INTERPOLATE COLOR PIXEL SIGNALS

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"Express Mail" label number *EL 03443 4615 US*

METHOD OF USING HUE TO INTERPOLATE COLOR PIXEL SIGNALS

RELATED APPLICATION

5   This patent application is a continuation-in-part of US Patent Application Serial No.

09/410,800, titled "Method of Interpolation Color Pixel Signals from a Subsampled Color

Image," by Acharya et al., filed on October 1, 1999, assigned to the assignee of the present

invention

and herein incorporated by reference.

10

BACKGROUND

This disclosure is related to interpolating color pixel signal values for an image and, in

particular, interpolating color pixel signal values using hue.

15

As is well-known, in a variety of circumstances, it is desirable to perform color

interpolation. For example, for a camera or other imager that has the capability of creating a

color image, typically it is too expensive to have the capability to capture three independent

color pixel signal values for each pixel location of an image at least on part because this

20   would employ additional sensors. Therefore, more typically, a subsampled color image is

captured and then the missing color pixel signal values are computed using techniques of

color interpolation. Most of the existing simple color interpolation techniques typically do not

produce high-quality color images. Therefore, a need continues to exist for color interpolation

techniques capable of producing quality color images from a subsampled color image.

BRIEF DESCRIPTION OF THE DRAWINGS

5

The subject matter regarded as the invention is particularly pointed out and distinctly

claimed in the concluding portion of the specification. The invention, however, both as to

organization and method of operation, together with objects, features, and advantages

thereof, may best be understood by reference to the following detailed description when read

10 with the accompanying drawings in which:

FIG. 1 is a schematic diagram illustrating a subsampled color image, such as a Bayer

pattern color mage;

15 FIG. 2 is a schematic diagram illustrating a portion of a subsampled color image in

which the color pixel signal values are to be employed by an embodiment of a method in

accordance with the present invention;

FIG. 3 is a schematic diagram illustrating a portion of another subsampled color image

20 in which the color pixel signal values are to be employed by an embodiment of a method in

accordance with the present invention;

FIG. 4 is a schematic diagram illustrating yet another portion of a subsampled color

image in which the color pixel signal values are to be employed by an embodiment of a

method in accordance with the present invention.

DETAILED DESCRIPTION

5   In the following detailed description, numerous specific details are set forth in order to

provide a thorough understanding of the invention. However, it will be understood by those

skilled in the art that the present invention may be practiced without these specific details. In

other instances, well-known methods, procedures, components and circuits have not been

described in detail so as not to obscure the present invention.

10   As previously indicated, in a variety of circumstances it may be desirable to have a

capability to interpolate color pixel signals from a subsampled color image in order to recover

the missing color components in a particular pixel location. FIG. 1 is a schematic diagram

illustrating a Bayer pattern color image, which is one example of a subsampled color image,

15   although the invention is not limited in scope in this respect. For example, many other well-

known subsampled color images may be employed and will provide satisfactory results. As

previously indicated, unfortunately, many color interpolation techniques typically do not

produce high-quality color images at least in part because the techniques employed typically

do not take into account, or at least reasonably correctly take into account, how the human

20   eye perceives color. For example, a typical color interpolation technique may include

averaging the pixels adjacent to a particular pixel location in which it is desired to interpolate

the color signal value for those colors not included in that pixel location of a subsampled color

image. However, typically, simply employing a pure average does not produce high quality

results at least in part because it may blur the edge information and produce a color bleeding

problem, for example.

In this particular embodiment of a method of using hue to interpolate color pixel signals in accordance with the present invention, color interpolation is accomplished by comparing, for a particular pixel location in a subsampled color image, relative differences in hue for two mutually orthogonal directions across the particular pixel location. Hue, in this context, for red and blue, refers to the relative signal value of a blue or red signal value to a green signal value at a given pixel location. It is assumed that if a significant change in hue occurs in a particular direction, the color pixel signal values in that direction are not as representative of the color pixel signal values at the particular pixel location as are the color pixel signal values from the mutually orthogonal direction. For example, it may be that in the image, an edge is being encountered. Therefore, in computing the color signal value for that particular pixel location, the change in hue for a direction that indicates less change in hue is weighed more heavily, in this particular embodiment. It is believed that this is more representative of how the human eye perceives color because the human vision system is more responsive to the relative change of color in neighboring pixels than to the color information in the pixel itself. In addition, as explained in more detail hereinafter, in computing pixel signal values for particular colors, the change in hue from both directions are weighed, instead of only using the change in hue from one direction to the exclusion of the other direction.

FIG. 2 is schematic diagram illustrating a portion of a five pixel-by-five pixel grid of the Bayer pattern of FIG. 1. As illustrated, the center pixel location comprises a red pixel signal value. Therefore, for this particular pixel location, it is desired to interpolate the missing color signal values, blue and green, for that pixel location from the surrounding pixel signal values.

For example, a green pixel signal value may be estimated as follows. First, the relative change in hue for the horizontal direction and the vertical directions with respect to this particular pixel location, designated below as RCH_hor and RCH_ver, respectively, may be computed and compared. This is accomplished using the following equations.

5 $$RCH\_hor = | \tfrac{1}{2} \times [- R_{m,n-2} + 2 G_{m,n-1} - 2 G_{m,n+1} + R_{m,n+2}] |$$

[1]

$$RCH\_ver = | \tfrac{1}{2} \times [- R_{m-2,n} + 2 G_{m-1,n} - 2 G_{m+1,n} + R_{m+2,n}] |$$

It is noted that for convenience, for the equations throughout the text of this specification, such

10 as equations [1] above, it is assumed that the pixel signal values employed, such as $R_{i,j}$ or $G_{i,j}$, for example, are the logarithm of the pixel signal values having the corresponding designation from the subsampled image.

If the relative change in hue in the vertical direction is greater than the relative change in hue in the horizontal direction, then the values in the horizontal direction, that is, in this

15 embodiment, the green and red pixel signal values that are the immediately adjacent pixel signal values in the horizontal direction, are weighed more heavily. In this embodiment, the weight assigned to these, 0.5 here, has been chosen based at least in part on fuzzy assignment concepts and experimentation, although the invention is not limited in scope in

20 this respect. It is noted that other weights may be employed and provide satisfactory results. At the same time, the weights assigned to vertical signal values have been chosen as 0.1, although the invention is not limited in scope in this respect. On the basis of the above discussion, the missing green pixel signal values in this particular pixel location is estimated, in this embodiment, as

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$$G_{m,n} = [\ 0.5 * (Ihor)\ +\ 0.1 * (Iver)\ ]\ /\ (0.5\ +\ 0.1);\ \text{or}$$

$$G_{m,n} = 2[0.41667 * (Ihor)\ +\ 0.08333 * (Iver)];$$

5   where   [2]

$$Ihor = (G_{m-1,n} + G_{m+1,n})/2 + 0.5 \times (-R_{m-2,n} + 2\ R_{m,n} - R_{m+2,n})/4$$

$$Iver = (R_{m,n-1} + R_{m,n+1})/2 + 0.5 \times (-R_{m,n-2} + 2\ R_{m,n} - R_{m,n+2})/4$$

10   If the relative change in hue in the horizontal direction is greater than the relative change in hue in the vertical direction, then a reverse approach is employed. More particularly, the pixel signal signal values in the alternate directions, in this particular embodiment, are weighed more heavily. In particular, the green pixel signal value in this particular pixel signal location for such a situation is estimated as follows.

15

$$G_{m,n} = 2[0.08333 * (Ihor)\ +\ 0.41667 * (Iver)];$$

It is noted that the form of this equation is similar to the form above, except that the vertical and horizontal pixel signal values that were computed are interchanged. Finally, if the two

20   relative changes are equal, or substantially equal, then a simple average of Iver and Ihor are employed in this embodiment.

$$G_{m,n} = 0.5 * (Ihor + Iver);$$

Therefore, in order to compute the signal value for the green color plane, where the particular

pixel location has a pixel signal value in the red color plane, the relative change in hue in

mutually orthogonal directions is compared. It is noted that where the particular pixel location

has a blue pixel signal value in the Bayer pattern shown in FIG. 1, the structure of a five pixel-

5   by-five pixel portion of the sub-sampled color image is similar in arrangement to that illustrated

in FIG. 2, except the center pixel contains blue signal information instead of red signal

information. Therefore, for a pixel location containing a blue signal value, in this embodiment,

the missing green pixel signal value for that pixel location may be estimated by using a

technique essentially the same as one previously described, replacing the red pixel signal

10   value used in the equations above for a particular location with the blue pixel signal value for

the particular location now being considered.

     FIG. 3 is schematic diagram of another portion of the Bayer pattern of FIG. 1. This

three pixel-by-three pixel portion is similar to a three-by-three portion of FIG. 2, except that

15   pixel signal values in the respective corners of the three-by-three array have also been

provided. For this portion, it is desirable to interpolate a blue pixel signal value for the

location in which a red pixel signal value is provided. However, as illustrated in FIG. 3, blue

pixel signal values immediately adjacent to the red pixel signal value are provided in the

corners. Therefore, in contrast with the approach just described, the two mutually orthogonal

20   directions to be compared comprise the main diagonal and the secondary diagonal of the

array of pixels. Therefore, the relative change in hue across these two diagonals shall be

compared. Hue, in this context, for red and blue, refers to the relative signal value of a blue or

red signal value to a green signal value at a given pixel location. As previously indicated, the

reason this approach is employed is because it is believed that hue information more

accurately reflects how the human eye perceives changes in color. Furthermore, a comparison for red and blue pixel signal values is made with green pixel signal values because, in Red-Green-Blue (RGB) color space format, the green plane includes a relatively larger amount of luminosity signal information compared to the red and blue planes. Hue for

5 red or blue signal values, therefore, is estimated by comparison with the green value. Therefore, hue for the four blue pixel signal values is computed by comparing the blue pixel signal value in that location with the green pixel signal value in that location. It should be noted that the missing green pixel value has already been or may be recovered via the previous technique. Therefore, the following equations apply.

10

$$hue\_nw = B_{m-1,n-1} - G_{m-1,n-1};$$

$$hue\_sw = B_{m+1,n-1} - G_{m+1,n-1};$$

[3]

15

$$hue\_ne = B_{m-1,n+1} - G_{m-1,n+1};$$

$$hue\_se = B_{m+1,n+1} - G_{m+1,n+1};$$

Then, the related change in hue along the main diagonal and the secondary diagonal may be computed as follows.

20

$$hue\_md = |\ hue\_nw - hue\_se\ |;$$

[4]

$$hue\_sd = |\ hue\_ne - hue\_sw\ |;$$

As discussed above, if the hue in any particular direction changes more significantly, then the hue in the mutually orthogonal direction is employed to estimate the blue pixel signal value in a particular pixel location. More accurately, that direction in which there is less relative change in hue is weighed more heavily than in the direction in which the relative change in

5 hue is greater. Employing the relative change in hue in this fashion, the blue pixel signal value may be estimated as follows, assuming the relative relative change in hue along the main diagonal is less.

$$B_{m,n} = (G_{m,n}) + 0.41667 * ((B_{m-1,n-1} - G_{m-1,n-1}) + (B_{m+1,n+1} - G_{m+1,n+1})) +$$

10 [5]

$$0.08333 * ((B_{m-1,n+1} - G_{m-1,n+1}) + (B_{m+1,n-1} - G_{m+1,n-1}));$$

Likewise, a similar equation is employed for the opposing diagonal, except that the signal

15 values along the diagonals are interchanged, providing the following equation.

$$(B_{m,n}) = (G_{m,n}) + 0.08333 * ((B_{m-1,n-1} - G_{m-1,n-1}) + (B_{m+1,n+1} - G_{m+1,n+1})) +$$

[6]

$$0.41667 * ((B_{m-1,n+1} - G_{m-1,n+1}) + (B_{m+1,n-1} - G_{m+1,n-1}))$$

20

It is noted that interpolation of a red pixel signal value for a particular pixel location having a blue pixel signal value may be obtained using a similar approach except that in the above equation the blue pixel signal values are interchanged with red pixel signal values. This is because, as illustrated in FIG. 1, where the particular pixel location has a blue pixel

signal value, the pixel signal values in the four corners are red pixel signal values, providing

substantially the same structure or array layout as illustrated in FIG. 3. Finally, a blue pixel

signal value may be interpolated where a green pixel signal value is provided in the particular

pixel location of the subsampled image, as illustrated in FIG. 4, for example. The approach is

5   similar to that described in connection to the approach described with FIG. 3, except that,

instead of employing the pixel signal values along the diagonals, the horizontal and vertical

pixel signal values are employed using either horizontal or vertical pixel signal value directly

available from the subsampled color image. The other pixel value in the orthogonal direction

which is used for interpolation is obtained by employing the previous calculation. For

10   example, the blue pixel signal values in the horizontal locations immediately adjacent the

green pixel signal values in FIG. 4 are interpolated using the approach just described above

in connection with FIG. 3. Therefore, the following equations are employed.

$$hue\_n = B_{m-1,n} - G_{m-1,n};$$

$$hue\_e = B_{m,n+1} - G_{m,n+1};$$

[7]

$$hue\_w = B_{m,n-1} - G_{m,n-1};$$

$$hue\_s = B_{m+1,n} - G_{m+1,n};$$

$$hhor = hue\_e - hue\_w;$$

$$hver = hue\_n - hue\_s,$$

where $B_{m,n+1}$ and $B_{m,n-1}$ are obtained from the previous interpolation calculation.

if (| hhor| < |hver|) *then*

$$(B_{m,n}) = (G_{m,n}) + 0.41667 * ((B_{m,n-1} - G_{m,n-1}) + (B_{m,n+1} - G_{m,n+1})) +$$

$$0.08333 * ((B_{m-1,n} - G_{m-1,n}) + (B_{m+1,n} - G_{m+1,n})).$$

else

$$(B_{m,n}) = (G_{m,n}) + 0.08333 * ((B_{m,n-1} - G_{m,n-1}) + (B_{m,n+1} - G_{m,n+1})) +$$

$$0.41667 * ((B_{m-1,n} - G_{m-1,n}) + (B_{m+1,n} - G_{m+1,n}))$$

5 ***endif***

A similar approach may be employed to interpolate the red pixel signal value where the particular pixel location of the subsampled image includes a green pixel signal value, except that in the equations provided above, the blue pixel signal values are replaced by red pixel signal values, as follows

10

$$\text{hue\_n} = R_{m-1,n} - G_{m-1,n} ;$$

$$\text{hue\_e} = R_{m,n+1} - G_{m,n+1} ;$$

$$\text{hue\_w} = R_{m,n-1} - G_{m,n-1} ;$$

15   [8]

$$\text{hue\_s} = R_{m+1,n} - G_{m+1,n} ;$$

$$\text{hhor} = \text{hue\_e} - \text{hue\_w} ;$$

$$\text{hver} = \text{hue\_n} - \text{hue\_s},$$

20 where $R_{m-1,n}$ and $R_{m+1,n}$ (or $R_{m,n-1}$ and $R_{m,n+1}$ depending on whether the particular pixel is located in the red-green row or blue-green row) are obtained from the previous interpolation calculation.

if (| hhor| < |hver|) ***then***

$$(R_{m,n}) = (G_{m,n}) + 0.41667 * ((R_{m,n-1} - G_{m,n-1}) + (R_{m,n+1} - G_{m,n+1})) +$$

$$0.08333 * ((R_{m-1,n} - G_{m-1,n}) + (R_{m+1,n} - G_{m+1,n})).$$

else

5 $$(R_{m,n}) = (G_{m,n}) + 0.08333 * ((R_{m,n-1} - G_{m,n-1}) + (R_{m,n+1} - G_{m,n+1})) +$$

$$0.41667 * ((R_{m-1,n} - G_{m-1,n}) + (R_{m+1,n} - G_{m+1,n}))$$

endif

10 It will, of course, be appreciated that the invention is not restricted in scope to a particular embodiment or implementation. For example, the foregoing approach, as one example of an approach in accordance with the invention, may be implemented in hardware, in software, in firmware, and/or any combination thereof. Again, intended merely as examples that do not limit the scope of the invention, an embodiment may comprise an imager including hardware, such as integrated circuit chips, that implement the foregoing. Alternatively, the

15 imager may be coupled to a computing platform that includes software capable of implementing the foregoing. Likewise, a digital camera coupled to a desktop personal computer, for example, may implement an embodiment. Furthermore, these implementations in hardware and software may, of course, deviate from the foregoing and still be within the scope of the present invention.

20

For embodiments that are at least partially implemented in software, such as, for example, the previously described embodiment, such software may reside on a storage medium, such as, for example, random access memory, a CD ROM, a floppy disk, or a hard drive, such that instructions are stored, which, when executed, such as by a computing

platform, such as a PC or other computing device, so that the system is capable of executing the instructions to result in the interpolation of color pixel signal values from a subsampled image. Likewise, such software may reside in firmware also, such as in flash memory or EEPROM, for example.

5

While certain features of the invention have been illustrated and described herein, many modifications, substitutions, changes and equivalents will now occur to those skilled in the art. It is, therefore, to be understood that the appended claims are intended to cover all such modifications and changes as fall within the true spirit of the invention.

Claims:

1 1. A method of using hue to interpolate color pixel signal values comprising:

2 for a particular pixel location in a subsampled image, comparing relative changes in

3 hue for two mutually orthogonal directions across said particular pixel location; and

4 computing a color signal value for that particular pixel location for a color plane other

5 than the color plane of the pixel signal value in the subsampled color image at that location,

6 the computation including relatively weighing the relative changes in hue, the relative weights

7 depending, at least in part, on the difference in hue value in one particular direction relative to

8 the other.

1 2. The method of claim 1, wherein computing a color signal includes relatively weighing

2 the differences in hue by relatively weighing more heavily the difference in hue associated

3 with the direction having a difference in hue less relatively for the particular pixel location.

1 3. The method of claim 2, wherein the subsampled image comprises an image in RGB

2 color space format.

1 4. The method of claim 3, wherein the subsampled color image comprises a Bayer

2 pattern.

1 5. The method of claim 4, wherein the color plane of the pixel signal value at said

2 particular pixel location comprises the R color plane;

3 the two mutually orthogonal directions comprising the horizontal and vertical directions;

4   the particular color plane for the color signal value being computed comprising the G

5   plane.

1   6.   The method of claim 4, wherein the color plane of the pixel signal value at said

2   particular pixel location comprises the B color plane;

3   the two mutually orthogonal directions comprising the horizontal and vertical direction;

4   and

5   the particular color plane for the color signal value being computed comprising the G

6   plane.

1   7.   The method of claim 4, wherein the color plane of the pixel signal value at said

2   particular pixel location comprises the R color plane;

3   the two mutually orthogonal direction comprising the main diagonal and the secondary

4   diagonal directions;

5   the particular color plane for the color signal value being computed comprising the B

6   plane.

1   8.   The method of claim 7, wherein the interpolation of a blue pixel signal value at a green

2   pixel location is based at least in part on computed B pixel signal value levels for red pixel

3   locations adjacent said green pixel location and also on existing blue pixel locations adjacent

4   said green pixel location in a mutually orthogonal direction to said adjacent red pixel locations

5   in the subsampled color image.

1   9.   The method of claim 4, wherein the color plane of the pixel signal value at said

2 particular pixel location comprises the B color plane;

3 the two mutually orthogonal directions comprising the main diagonal and the secondary

4 diagonal directions;

5 the particular color plane for the color signal value being computed comprising the R

6 plane.

1 10. The method of claim 9, wherein the interpolation of a red pixel signal value at a green

2 pixel location is based at least in part on computed R pixel signal value levels for blue pixel

3 locations adjacent said green pixel location and also on existing red pixel locations adjacent

4 said green pixel location in a mutually orthogonal direction to said adjacent blue pixel

5 locations in the subsampled color image.

1 11. The method of claim 4, wherein the color plane of the pixel signal value at said

2 particular pixel location comprises the G color plane;

3 the two mutually orthogonal direction comprising the horizontal and the vertical

4 directions;

5 the particular color plane for the color signal value being computed comprising the B

6 plane.

1 12. The method of claim 4, wherein the color plane of the pixel signal value at said

2 particular pixel location comprises the G color plane;

3 the two mutually orthogonal direction comprising the horizontal and the vertical

4 directions;

5 the particular color plane for the color signal value being computed comprising the R

6   plane.

1   13.   An article comprising:

2   a storage medium, having stored thereon instructions, which, when executed by a

3   system capable of executing the instructions, result in interpolating color pixel signal values

4   from a subsampled image by:

5   for a particular pixel location in the subsampled image, comparing changes in hue for

6   two mutually orthogonal directions across said particular pixel location; and

7   computing a color signal value for that particular pixel location for a color plane other

8   than the color plane of the pixel signal value in the subsampled color image at that location by

9   relatively weighing the differences in hue, the relative weights depending, at least in part, on

10   the difference in hue in a particular direction relative to the other direction.

1   14.   The article of claim 13, wherein the instructions, when executed, further result in

2   interpolating color pixel signal values from a subsampled image in RBG color space format.

1   15.   The article of claim 13, wherein the instructions, when executed, further result in

2   interpolating color pixel signal values from a Bayer pattern image.

1   16.   An integrated circuit comprising;

2   electronic circuitry adapted to process pixel signal values;

3   wherein said electronic circuitry is further adapted to interpolate color pixel signal

4   values from a subsampled image by:

5   for a particular pixel location in the subsampled image, comparing changes in hue for

6 two mutually orthogonal directions across said particular pixel location; and

7   computing a color signal value for that particular pixel location for a color plane other

8 than the color plane of the pixel signal value in the subsampled color image at that location by

9 relatively weighing the differences in hue, the relative weights depending, at least in part, on

10 the difference hue in a particular direction relative to the other direction.

1 17.   The integrated circuit of claim 16, wherein said electronic circuitry is further adapted to

2 interpolate color pixel signal values from a subsampled image in RBG color space format.

1 18.   The integrated circuit of claim 16, wherein said electronic circuitry is further adapted to

2 interpolate color pixel signal values from a Bayer pattern image.

1 19.   A system comprising;

2   a computing platform adapted to process pixel signal values;

3 wherein said computing platfrom is further adapted to interpolate color pixel signal values from

4 a subsampled image by:

5   for a particular pixel location in the subsampled image, comparing differences in hue

6 for two mutually orthogonal directions across said particular pixel location; and

7   computing a color signal value for that particular pixel location for a color plane other

8 than the color plane of the pixel signal value in the subsampled color image at that location by

9 relatively weighing the difference in hue, the relative weights depending, at least in part, on

10 the difference in hue in a particular direction relative to the other direction.

1 20.   The system of claim 19, wherein said computing platfrom is further adapted to

2   interpolate color pixel signal values from a subsampled image in RBG color space format.

ABSTRACT

Briefly, in accordance with one embodiment of the invention, a method of using hue to interpolate color pixel signals includes the following. For a particular pixel location in a subsampled color image, differences in hue are compared for two mutually orthogonal directions across the particular pixel location. A color signal value for that particular pixel location for a color plane other than the color plane of the pixel signal value in the subsampled color image of that location is computed. The computation includes relatively weighing the differences in hue values, the relative weights depending, at least in part, on the difference in hue value in one direction relative to the other.

R	G1	R	G1	R	G1	R	G1	...	...
G2	B	G2	B	G2	B	G2	B	...	...
R	G1	R	G1	R	G1	R	G1	...	
G2	B	G2	B	G2	B	G2	B	...	
R	G1	R	G1	R	G1	R	G1	...	
G2	B	G2	B	G2	B	G2	B	...	
R	G1	R	G1	R	G1	R	G1	...	
G2	B	G2	B	G2	B	G2	B	...	
:	:	:	:	:	:	:	:	...	

Figure 1: Bayer Pattern

		$R_{m-2,n}$		
		$G_{m-1,n}$		
$R_{m,n-2}$	$G_{m,n-1}$	$R_{m,n}$	$G_{m,n+1}$	$R_{m,n+2}$
		$G_{m+1,n}$		
		$R_{m+2,n}$		

Figure 2

B $_{m-1,n-1}$	G $_{m-1,n}$	B $_{m-,n+1}$
G $_{m,n-1}$	R $_{m,n}$	G $_{m,n+1}$
B $_{m+1,n-1}$	G $_{m+1,n}$	R $_{m+,n+1}$

Figure 3

	B $_{m-1,n}$	
R $_{m,n-1}$	G $_{m,n}$	R $_{m,n+1}$
	B $_{m+1,n}$	

Figure 4

(FOR <u>INTEL CORPORATION</u> PATENT APPLICATIONS)

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below, next to my name.

I believe I am the original, first, and sole inventor (if only one name is listed below) or an original, first, and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

METHOD OF USING HUE TO INTERPOLATE COLOR PIXEL SIGNALS

the specification of which

DECLARATION AND POWER OF *
(FOR <u>INTEL CORPORA7</u>

| X | is attached hereto.

☐ was filed on _____ as ____
United States Application Number _____
or PCT International Application Number _____
and was amended on _____ .
(if applicable)

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claim(s), as amended by any amendment referred to above. I do not know and do not believe that the claimed invention was ever known or used in the United States of America before my invention thereof, or patented or described in any printed publication in any country before my invention thereof or more than one year prior to this application, that the same was not in public use or on sale in the United States of America more than one year prior to this application, and that the invention has not been patented or made the subject of an inventor's certificate issued before the date of this application in any country foreign to the United States of America on an application filed by me or my legal representatives or assigns more than twelve months (for a utility patent application) or six months (for a design patent application) prior to this application.

I acknowledge the duty to disclose all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, Section 119(a)-(d), of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

Prior Foreign Application(s):

APPLICATION NUMBER	COUNTRY (OR INDICATE IF PCT)	DATE OF FILING (day, **month**, year)	PRIORITY CLAIMED UNDER 37 USC 119
			☐ No ☐ Yes
			☐ No ☐ Yes
			☐ No ☐ Yes

I hereby claim the benefit under Title 35, United States Code, Section 119(e) of any United States provisional application(s) listed below:

APPLICATION NUMBER	FILING DATE

I hereby claim the benefit under Title 35, United States Code, Section 120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, Section 112, I acknowledge the duty to disclose all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application:

APPLICATION NUMBER	FILING DATE	STATUS (ISSUED, PENDING, ABANDONED)
09/410,800	10/1/99	Pending

I hereby appoint the persons listed on Appendix A hereto (which is incorporated by reference and a part of this document) as my respective patent attorneys and patent agents, with full power of substitution and revocation, to prosecute this application and to transact all business in the Patent and Trademark Office connected herewith.

Send correspondence to:
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(Name of Attorney or Agent)
12400 Wilshire Boulevard, 7th Floor, Los Angeles, California 90025 and direct telephone calls to:
Howard A. Skaist, (503) 684-6200.
(Name of Attorney or Agent)

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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Inventor's Signature _____   Date _____

Residence _____   Citizenship _____
　　　　　　　　　　(City , State)　　　　　　　　　　　　　　　　*(Country)*

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_____

APPENDIX A

I hereby appoint BLAKELY, SOKOLOFF, TAYLOR & ZAFMAN LLP, a firm including: William E. Alford, Reg. No. 37,764; Farzad E. Amini, Reg. No. 42,261; Amy M. Armstrong, Reg. No. 42,265; Aloysius T. C. AuYeung, Reg. No. 35,432; William Thomas Babbitt, Reg. No. 39,591; Carol F. Barry, Reg. No. 41,600; Jordan Michael Becker, Reg. No. 39,602; Bradley J. Bereznak, Reg. No. 33,474; Michael A. Bernadicou, Reg. No. 35,934; Roger W. Blakely, Jr., Reg. No. 25,831; Gregory D. Caldwell, Reg. No. 39,926; Ronald C. Card, Reg. No. 44,587; Thomas M. Coester, Reg. No. 39,637; Donna Jo Coningsby, Reg. No. 41,684; Michael Anthony DeSanctis, Reg. No. 39,957; Daniel M. De Vos, Reg. No. 37,813; Robert Andrew Diehl, Reg. No. 40,992; Matthew C. Fagan, Reg. No. 37,542; Tarek N. Fahmi, Reg. No. 41,402; George L. Fountain, Reg. No. 36,374; Paramita Ghosh, Reg. No. 42,806; James Y. Go, Reg. No. 40,621; James A. Henry, Reg. No. 41,064; Willmore F. Holbrow III, Reg. No. 41,845; Sheryl Sue Holloway, Reg. No. 37,850; George W Hoover II, Reg. No. 32,992; Eric S. Hyman, Reg. No. 30,139; William W. Kidd, Reg. No. 31,772; Sang Hui Kim, Reg. No. 40,450; Eric T. King, Reg. No. 44,188; Erica W. Kuo, Reg. No. 42,775; Michael J. Mallie, Reg. No. 36,591; Paul A. Mendonsa, Reg. No. 42,879; Darren J. Milliken, Reg. No. 42,004; Chun M. Ng, Reg. No. 36878; Thien T. Nguyen, Reg. No. 43,835; Thinh V. Nguyen, Reg. No. 42,034; Dennis A. Nicholls, Reg. No. 42,036; Lisa A. Norris, Reg. No. 44,976; Daniel E. Ovanezian, Reg. No. 41,236; William F. Ryann, Reg. No. 44,313; James H. Salter, Reg. No. 35,668; William W. Schaal, Reg. No. 39,018; James C. Scheller, Reg. No. 31,195; Jeffrey S. Smith, Reg. No. 39,377; Maria McCormack Sobrino, Reg. No. 31,639; Stanley W. Sokoloff, Reg. No. 25,128; Judith A. Szepesi, Reg. No. 39,393; Vincent P. Tassinari, Reg. No. 42,179; Edwin H. Taylor, Reg. No. 25,129; Joseph A. Twarowski, Reg. No. 42,191; Lester J. Vincent, Reg. No. 31,460; Glenn E. Von Tersch, Reg. No. 41,364; John Patrick Ward, Reg. No. 40,216; Charles T. J. Weigell, Reg. No. 43,398; James M. Wu, Reg. No. 45,241; Steven D. Yates, Reg. No. 42,242; and Norman Zafman, Reg. No. 26,250; my attorneys; and Andrew C. Chen, Reg. No. 43,544; Justin M. Dillon, Reg. No. 42,486; and John F. Travis, Reg. No. 43,203; my patent agents, of BLAKELY, SOKOLOFF, TAYLOR & ZAFMAN LLP, with offices located at 12400 Wilshire Boulevard, 7th Floor, Los Angeles, California 90025, telephone (714) 557-3800, and Alan K. Aldous, Reg. No. 31,905; Robert D. Anderson, Reg. No. 33,826; Joseph R. Bond, Reg. No. 36,458; Richard C. Calderwood, Reg. No. 35,468; Jeffrey S. Draeger, Reg. No. 41,000; Cynthia Thomas Faatz, Reg No. 39,973; Sean Fitzgerald, Reg. No. 32,027; John N. Greaves, Reg. No. 40,362; Seth Z. Kalson, Reg. No. 40,670; David J. Kaplan, Reg. No. 41,105; Charles A. Mirho, Reg. No. 41,199; Leo V. Novakoski, Reg. No. 37,198; Naomi Obinata, Reg. No. 39,320; Thomas C. Reynolds, Reg. No. 32,488; Kenneth M. Seddon, Reg. No. 43,105; Mark Seeley, Reg. No. 32,299; Steven P. Skabrat, Reg. No. 36,279; Howard A. Skaist, Reg. No. 36,008; Steven C. Stewart, Reg. No. 33,555; Raymond J. Werner, Reg. No. 34,752; Robert G. Winkle, Reg. No. 37,474; and Charles K. Young, Reg. No. 39,435; my patent attorneys, and Thomas Raleigh Lane, Reg. No. 42,781; Calvin E. Wells; Reg. No. P43,256, Peter Lam, Reg. No. 44,855; and Gene I. Su, Reg. No. 45,140; my patent agents, of INTEL CORPORATION; and James R. Thein, Reg. No. 31,710, my patent attorney; with full power of substitution and revocation, to prosecute this application and to transact all business in the Patent and Trademark Office connected herewith.